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NBS PROJECT		NBS REPORT
1004-12-10448	30 April 1964	8339

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Thomas H. Boone
Organic Building Materials Section
Building Research Division

and

William A. Bender
Buildings and Grounds Branch, Military Construction Directorate
Office of the Chief of Engineers

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Office of the Chief of Engineers
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1. INTRODUCTION

Floors in kitchens, the adjoining dishwashing rooms, and preparation rooms for raw foods are subjected to extremely severe conditions. The floors are exposed to grease; cooking oils; fatty, vegetable, and fruit acids; frequent scrubbing and cleaning, sometimes with strong alkaline detergents; and around stoves to temperatures as high as 275°F (135°C). In many areas the floors are almost continuously wet from spillages around dishwashing machines, sinks, live steam pipes, and from the dumping of hot food liquids directly on the floor adjacent to, but usually many feet from, the floor drain (see Figure 1). Mechanical damage is also encountered such as the shuffling of feet at work tables and serving lines, the dragging or impact of the edge of fully loaded garbage cans and the agitation of stiff-bristled scrubbing brushes. It requires an exceptional floor to withstand such a combination of exposures.

From the service life of floorings used in military kitchens, the following conclusions and opinions have been reported:*

(1) Portland cement concrete with well selected aggregate, properly mixed and placed, provided 3 to 4 years of service before areas adjacent to ranges, sinks, and drains were eroded severely and the aggregate exposed.

(2) A Portland cement concrete with high water-cement ratio, and/or poor curing had somewhat less service than that of a "good" concrete as just mentioned.

(3) Proprietary Portland cement concrete toppings over a thoroughly scarified and cleaned old concrete floor with all the recommended installation procedures carried out carefully, provided 4 to 7 years of service before areas adjacent to ranges, sinks, and drains were eroded severely.

(4) Magnesium oxychloride floors were not satisfactory in kitchen areas since the excessive amounts of water caused deterioration in less than one year.

*Boone, T. H., P. A. Sigler, and H. R. Snoke, "Evaluation of Flooring Materials in Army Installations", National Bureau of Standards Report No. 2485, May 11, 1953.

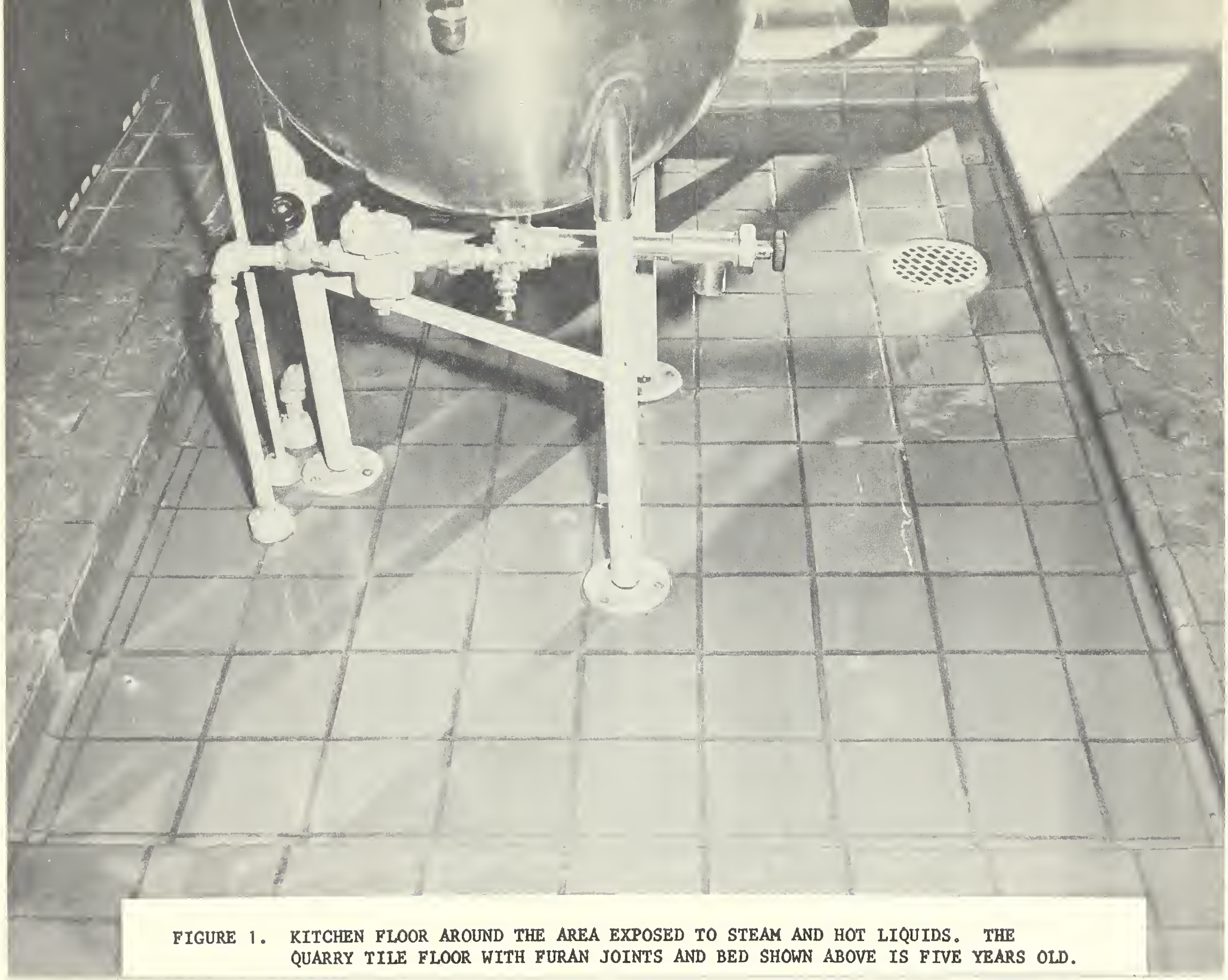

FIGURE 1. KITCHEN FLOOR AROUND THE AREA EXPOSED TO STEAM AND HOT LIQUIDS. THE QUARRY TILE FLOOR WITH FURAN JOINTS AND BED SHOWN ABOVE IS FIVE YEARS OLD.

(5) Thin floor coverings such as asphalt tile, vinyl asbestos tile, and rubber tile were not satisfactory. The tiles were damaged readily by impact and contact with hot cooking utensils. Bond failures were severe near areas of water spillage.

(6) Quarry tiles with Portland cement mortar jointing and bedding provided 3 to 4 years of service before joints eroded and the tiles became loose. The tiles remained in good condition. Some specially treated inorganic cement mortars extended the service from 4 to 7 years.

In order to find flooring systems which would provide a more extensive service in military kitchens than those mentioned above, test installations were made of recommended and laboratory tested flooring materials at military posts near Washington, D. C. During the past ten years a record has been kept of the methods of installation, the type of materials used, and the overall performance of these test floors. As new systems and new materials were developed, additional installations were made in kitchens as nearly similar in use and condition as the first.

Two approaches were made, first to investigate materials which could be troweled over the old concrete and second to investigate materials which could be used as bed and joints for quarry tile floors. It was hoped that either or both of these systems would provide 7 to 10 years of service under the harsh conditions encountered in the kitchens.

2. GENERAL DESCRIPTION OF THE TEST AREAS

The kitchens used in these experiments contained approximately 800 square feet of floor area and were in frame mobilization mess hall buildings constructed during World War II. Each kitchen contained the usual commercial kitchen equipment including three ranges, a deep fat fryer, two sinks, a dishwashing machine, a hot water heater and large storage tank, a heated serving table, refrigerated cabinets, and a dry storage room.

Each of the buildings selected were of the same size and type, and used for the same purpose, i.e. to prepare and serve food; three meals a day for approximately 200 men a meal.

Originally the kitchens were floored with strip-pine over 1-inch thick subfloor placed on 2- by 8-inch joints 12 inches on center. Within a short time these wood floors deteriorated badly and were repaired by covering with 2-1/2- to 4-inch thick reinforced concrete. Extra supporting columns and beams were placed under the floors.

3. EXPERIMENTAL TEST FLOORS

The flooring materials selected for this investigation were latex-modified cements, latex cement compounds, resin-based thermosetting surfacing compounds, and quarry tile floors with resin-based thermosetting bed and joints.

From the beginning of these experimental installations, it was recognized that even the best materials could be jeopardized by careless or untrained mechanics. The test floors that are described in this paper were therefore placed under the best possible conditions. Highly skilled mechanics, thoroughly familiar with the products and in most cases employees of the manufacturer were used to install the floors. All recommendations of the manufacturers as to the method, thickness, and conditions of application were followed.

None of the flooring systems were designed for or intended to add or provide strength to the floor.

Only those floors that were exposed to comparable service are reported.

3.1 Latex-modified Cement and Latex Cement

The latex-modified cements were composed of cement, aggregate, and latex (see Table I). The addition of latex of approximately 5% solids, based on the total solids of the composition, was claimed to give good bonding strength to clean substrate, allow for thinner coatings, and offer higher chemical resistance.

The sample designated as floor number 1 was a concrete modified with styrene-butadiene latex and placed 3/4-inch thick over concrete. The floor had a very high dirt retention. Within three months signs of erosion were noted around the floor drain. In a little over one year the erosion of the matrix throughout the kitchen area had caused a physical breakdown to an extent that the experiment was discontinued and the floor removed.

Floor number 2, which was identical to floor number 1, except a polyvinylidene chloride latex was used, failed in a little over one year because of severe erosion.

The latex cement floors, numbers 3, 4, and 5, were prepared from a mixture of inert aggregate, latex, and high alumina cement (see Table I). The resistance to erosion depends on the type of cement and latex used. In general, a high latex-alumina cement mixture will withstand more acidic conditions than alumina cement alone. Three installations were made over concrete with a latex containing

Table I. Formulation of Latex Floors

Floor number	Parts by Weight 1	2	3 Base Coat	3 Top Coat	4 & 5
Inert fillers	3.0	3.0	3.0	3.0	3.0
Portland cement	1.0	1.0			
Alumina cement			1.0	1.0	1.0
Latex	0.4 1/	0.4 2/	0.4 3/	0.9 3/	0.9 3/
Water	0.1	0.1			

1/ Styrene/butadiene latex containing 48% solids.

2/ Polyvinylidene chloride latex containing 48% solids.

3/ Polyvinyl chloride latex containing 40% solids.

a high percentage of a vinyl latex with alumina cement. Floor number 3 was placed in two coats to a total thickness of 3/8-inch over a latexed primed concrete. The other two floors, 4 and 5, were placed with the same thickness in one coat over latexed primed concrete.

All three floors had very low resistance to abrasion when wet and were softened by heat. The materials were worn down to the substrate in heavy traffic areas in a little over one year.

A summary of the results of the latex floors is given in Table III.

3.2 Resin-based Thermosetting Floor Toppings

The epoxy toppings have been widely used as a corrosion-resistant shield over industrial concrete floors because of their ability to withstand heavy traffic and to prevent the deterioration of concrete floor slabs due to acids, alkalies, and solvents. The characteristics of cast concretes prepared with epoxy resins have been examined and compared with inorganic concrete by many laboratories. In general it can be stated from laboratory results that the epoxy resin concrete has higher compressive and tensile strength; the shrinkage of certain floor mixes corresponds with that of Portland cement concrete; swelling is less and creep is no higher and may be lower than Portland cement concrete. Because of its resistance to chemicals it is unquestionably more suitable for certain applications.

The principal ingredients of epoxy floors are epoxy resin, hardener, and filler. The epoxy resin is the binder which holds the mass together and bonds it to the base floor. The hardener converts the liquid epoxy resin into a solid. The filler, which can be of most any material fairly inert to chemicals, adds to the impact strength and brings the coefficient of thermal expansion of the epoxy closer to that of the base slab.

Two monolithic epoxy floors, numbers 6 and 7, were placed by corrosion-engineering concerns specializing in chemical resistant linings and floorings. A brief formulation of floors 6 and 7 are given in Table II.

Floor number 6 was placed on a roughened, cleaned and dry concrete in August 1959. The temperature at the floor level remained at approximately 75°F (24°C) during the installation and for 4 days after installation. An epoxy primer was brushed onto the concrete and the topping was placed 1/4-inch thick in one application. The building was not occupied for 30 days.

Table II. Formulation of Epoxy Toppings and Mortars

Floor number	Parts by Weight				
	6	7		8	
		Base Coat	Top Coat	Bed	Joint
Inert filler	5.0	3.0	8.0	4.0	1.5
Epoxy resin	1.0	0.7	0.7	0.7	0.7
Hardener	0.1	0.3	0.3	0.3	0.3

Table III. Summary of Results of Experimental Floors

Floor number	Age of floor years	Duration before major failure years	Cause of failure: poor bond	heat	erosion	wear	impact
Latex-modified cement							
1	1	1			X		
2	1	1			X		
Latex cement							
3	1	1	X	X	X	X	
4	1	1	X	X	X	X	
5	1	1	X	X	X	X	
Monolithic epoxy							
6	3	3	X	X			
7	1	1	X	X		X	X
Quarry tile-epoxy							
8	4	4	X	X			
9	3[1]						
Quarry tile-furan							
10	9[2]						

[1] The kitchen containing this test floor has only been occupied about 50% of the 3-year period.

[2] This floor has had no major failures and is still in use.

Within one year small sections of the floor had to be replaced near the ranges and at the floor drains. By 1962 large sections of the epoxy had delaminated from the concrete and were no longer serving their function. Chemical degradation of the epoxy flooring seems to be taking place in areas of high temperature.

The concrete base of floor number 7 was cleaned with a hydrochloric acid solution, scrubbed, thoroughly rinsed with water, and dried. This installation was placed in August 1959, under the same conditions and temperatures as floor number 6. An epoxy sandfilled base coat was placed 1/16-inch thick with a glass matt overlay. A non-filled epoxy was worked into the top surface of the matt. Over this was placed two coats, a 3/16-inch filled coating and a high resin content skim coat (see Figure 2). The building was not occupied for 20 days.

Within one month the following observations were made:

(1) bond failure between base epoxy and concrete at areas near ranges,

(2) separation of skim coat from the body of the epoxy around the floor drain area,

(3) numerous indentation spots caused by impact of food serving trays and garbage cans.

By the fall of 1960, this floor had completely failed. Large sections had delaminated, other sections had broken away from the concrete.

A summary of the results of the monolithic epoxies are given in Table III.

3.3 Quarry Tile Floors with Resin-based Thermosetting Bed and Joints

The weaknesses or faults which have been noticed in quarry tile floors used in kitchens were the slipperiness of the smooth tile surfaces, the early breakdown of the joint materials and the need of a rigid subfloor.

Non-slip conditions were obtained by using tile with aluminum oxide particles embedded in the surface. Two thermosetting resins, epoxy and furan, were investigated for better joints and bed mortars. A floor design was used on floors numbers 9 and 10 that would permit the installation of quarry tile over wood (see Figure 3).

The old concrete surface in the kitchen for floor number 8 was cleaned with hydrochloric acid solution, scrubbed, thoroughly rinsed with water, and dried. An epoxy primer was brushed on the concrete, and

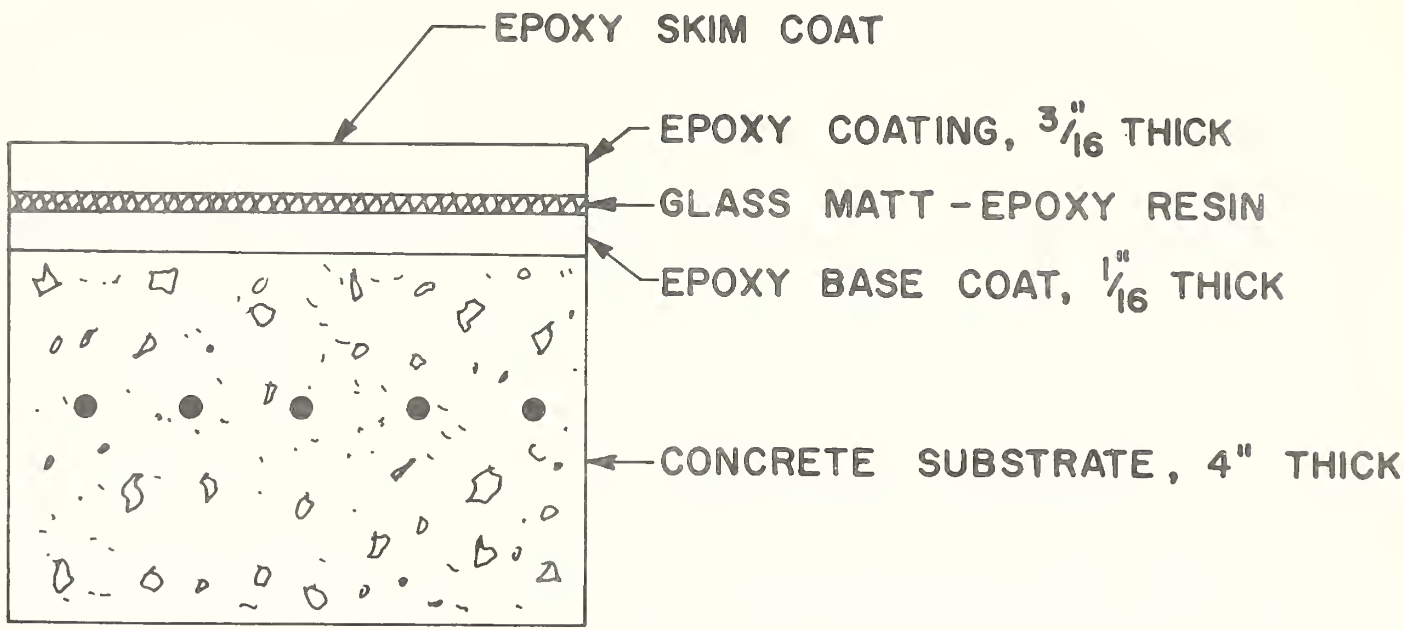

FIGURE 2. SCHEMATIC DIAGRAM OF TEST FLOOR NUMBER 7, MULTI-LAYER EPOXY COATINGS.

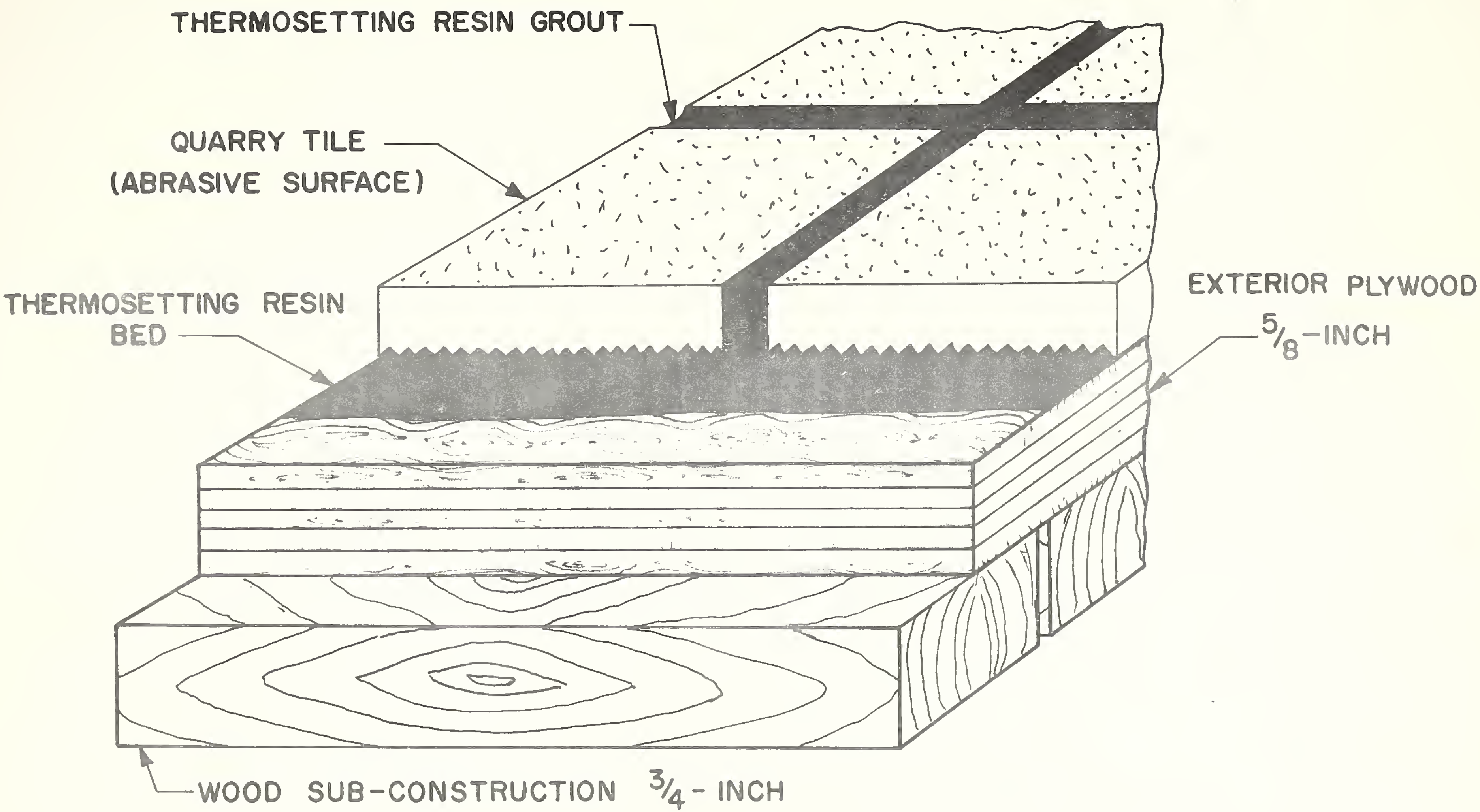

FIGURE 3. QUARRY TILE FLOOR CONSTRUCTION OVER WOOD SUBFLOORING.

the epoxy resin bed composition as given in Table II was placed 3/4-inch thick and the tiles set into the bed with 1/4-inch wide joints. The tiles were 6- by 6- by 1/2-inch. The backs of the tiles were "V" scored or grooved about 1/16-inch deep. The face surfaces were embedded with aluminum oxide abrasive particles and coated with wax. When the epoxy resin cement mortar setting bed had set hard, freshly mixed epoxy mortar was spread and worked into the joints of the tile. The floor area was allowed to remain undisturbed for three days before cleaning the top surfaces of the tiles.

The first signs of deterioration were noted after 2 years of service. The epoxy joints under and adjacent to the ranges and the hot water heater had completely failed and could be removed by hand. By the fourth year the floor had to be replaced. On lifting the tiles it was noted that the binder in the base epoxy had completely disintegrated leaving only the sandy fill which was easily and completely swepth away exposing the old concrete surface.

The concrete was removed in the kitchen used for floor number 9 and 5/8-inch thick exterior grade waterproofed plywood in 8- by 8-foot sheets was placed over the sheathing. The end joints of the plywood were staggered and securely nailed on 6-inch centers in two directions with hot-dipped galvanized flat head nails 1-3/4 inch long.

The epoxy bed* was spread over the cleaned plywood with a notched trowel having 3/8-inch deep notches 1/4-inch apart.

From this point on, the same type of tiles and the same method of application were used as in floor number 8, except that no wax was placed on the face of the tiles, and the tiles were cleaned just after setting of the joints.

This kitchen has been occupied only 50% of the three years since its installation. Softening of the epoxy joints near the heated ranges has been noted.

Test floor number 10 was installed over plywood similar to floor number 9 and illustrated in Figure 3, except that furan resin was used as the bed and joint and the top surfaces of the tiles were waxed.

*The manufacturer of this product would not reveal its formulation.

Furan resin is a furfuryl alcohol resin, which, when treated with a suitable acid catalyst system, polymerizes into a thermosetting solid resin.

This floor was installed in the winter of 1954-55 by tile setters inexperienced at working with thermosetting resin mortars. Difficulty was encountered in mixing the compound, in obtaining a completely cured floor, and in cleaning the tile surface.

With the exception of a few hairline cracks in the joints and a small amount of tile impact damage this floor has performed very satisfactorily for 9 years (see Figure 4). Many other military kitchen floors of furan and quarry tile have also performed satisfactorily since 1958.

A summary of the results of the quarry tile floors with epoxy and furan are given in Table III.

4. ACKNOWLEDGMENT

The authors acknowledge with thanks the tecnical advice and services given by the following concerns: The Atlas Mineral Products Company; Bisonite Company, Inc.; The Camp Company, Inc.; The Ceilcote Company; Dasco Chemicals Company; The Dow Chemical Company, Plastics Department; Flintkote Company, Industrial Products Division; International Pipe & Ceramics Corporation, Electro-Chemical Products; Tile Council of America, Inc.

FIGURE 4. TEST FLOOR NUMBER 10, QUARRY TILE WITH FURAN JOINTS AND BED. WITH THE EXCEPTION OF A FEW HAIRLINE CRACKS IN THE JOINTS AND A SMALL AMOUNT OF TILE IMPACT DAMAGE THIS FLOOR HAS PERFORMED VERY SATISFACTORILY FOR NINE YEARS.

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